The Tritium Tempest in a Teapot

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Problem Summary

The trouble with tritium is there *is* no trouble with tritium.*

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* Title of article by Conca published by American Nuclear Society in October 2022

Setting the Stage

- Conca is scientist in field of earth and environmental sciences, specializing in geologic disposal of nuclear waste, energy-related research, planetary surface processes, radiobiology and shielding for space colonies, subsurface transport and environmental clean-up of heavy metals
- Article written to counter public scaremongering initiated by plan to dispose of tritiated water from Fukushima nuclear power plant accident by discharging it to Pacific Ocean
- Ostensibly, tritium health concern from internal radiation exposure following ingestion of contaminated seafood
- Following slides will show why tritiated water disposal issue gets much more attention than it deserves

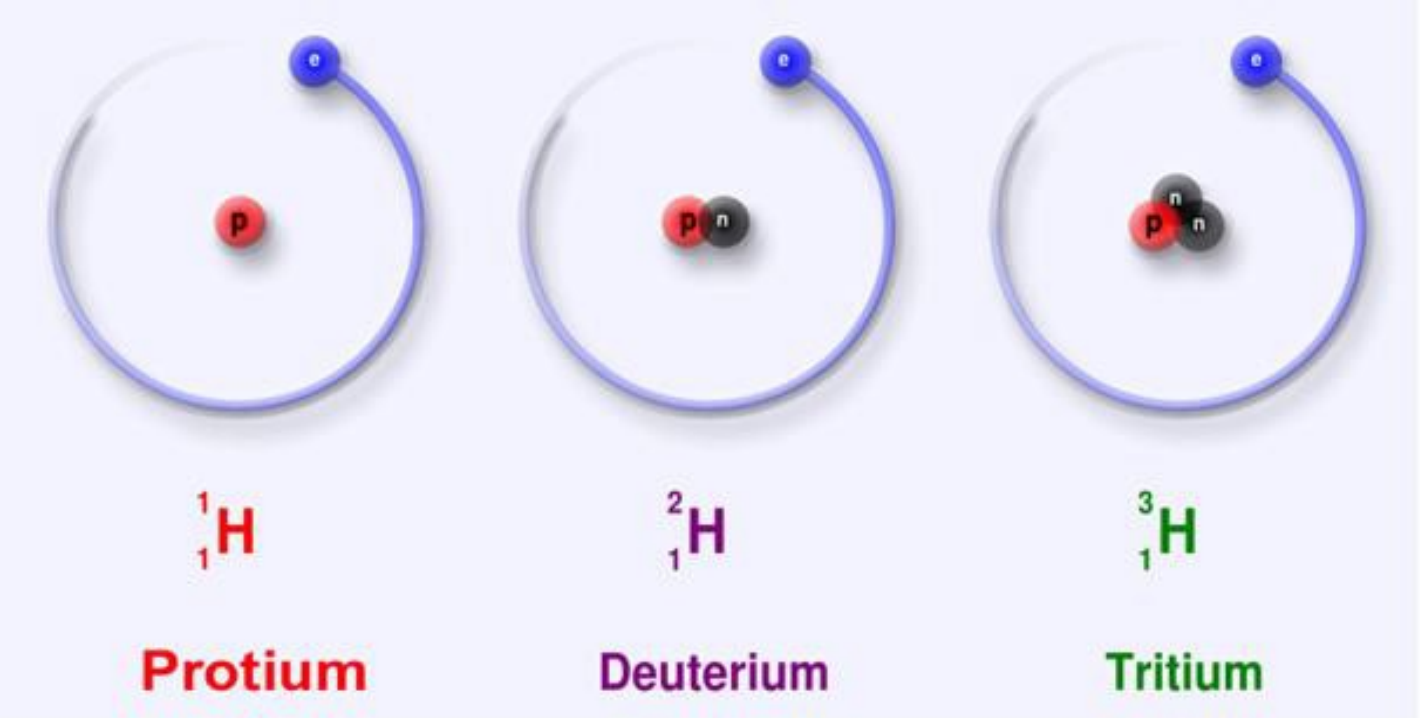
Fukushima Tritiated Water Tanks

Fukushima Tritiated Water Controversy

The Real Problem: Many people who are very angry with decision to dump tritiated water from Fukushima accident into Pacific Ocean

- Those who know it's not genuine health concern, but spread false information to advance anti-nuclear agenda
- Many more who uncritically repeat disinformation
- The masses who become frightened because they willingly believe what they are told

Isotopes of Hydrogen



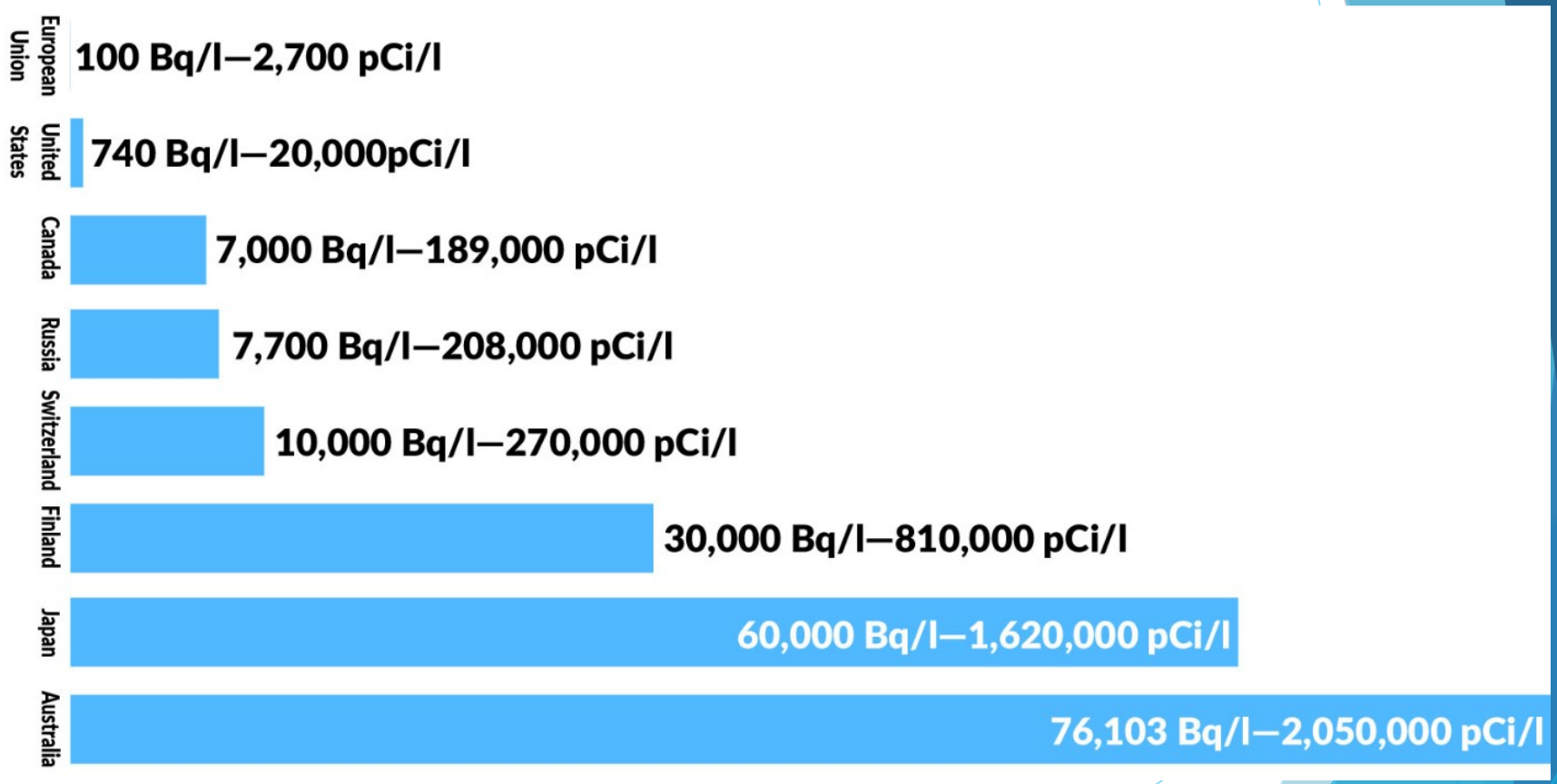
Tritium Production

- Harmless levels of tritium generated in normal industrial processes
- More tritium created continuously in Earth's upper atmosphere from neutron activation of nitrogen (N-14 + neutron → C-12 + H-3) than produced by nuclear reactors
- Reactor-generated tritium reacts with oxygen in reactor cooling water just as does protium to produce HTO (tritiated water)

Natural Tritium in Environment

- Natural tritium in waters of the Earth present at concentrations that range from 0.185 to 0.925 Becquerel per liter (Bq/L) of water.[1]
- Tritium so harmless that maximum regulatory limits in drinking water range from low of 100 Bq/L (European Union) to high of 76,000 Bq/L (Australia)[2] – orders of magnitude higher than naturally occurring levels

Tritium in Drinking Water Regulatory Limits



Tritium Biological Facts

- Tritium has weakest radioactivity of any radionuclide, with decay energy of 18.6 keV (5.7 keV for beta particle and 12.9 keV for associated anti-neutrino)
- Low-energy beta particle has extremely limited range in biological material (< 10 μm), depositing energy primarily through inelastic collisions with atomic electrons of cellular matter[1]

Tritium Biological Facts (cont.)

- While tritium radiological half-life is 12.3 years, biological half-life only about 10 days (i.e., ≈4500 times more likely to be excreted than to decay internally)
  - Thermodynamically prefers to exist as water (HTO)[1]
  - No observed tritium concentration in biological material
  - Roughly 60% of body weight is water; 5 tritium atoms per 10^{18} hydrogen atoms[2] → ≈ 1.7 x 10^{-14} gram tritium in human body
  - Tritium radioactivity in human body about 59 Becquerels per liter,[2] well below EU regulatory limit for drinking water
  - 55% excreted in urine, 29% through skin, 12% in exhaled air
  - Excess tritium ingestion remediation plan – drink lots of beer

Biological Tritium in Perspective

To put tritium “concern” in proper perspective, consider two radionuclides that present internal radiation exposures that aren’t health concerns – carbon-14 (C-14) and potassium-40 (K-40)

- Like tritium, C-14 and K-40 radioactively decay by beta particle emission (K-40 also emits gamma-ray)
- C-14 plentiful in human body because we are carbon-based life forms
- K-40 found everywhere in human environment, including food we eat

Biological Tritium in Perspective (cont.)

- Carbon-14 emits beta particle with energy of 157 keV (greater than 8 times energy of tritium beta)
- Carbon ≈ 23% of body weight; one C-14 atom for every trillion carbon atoms[1] → ≈ 1.6 x 10^{-8} gram C-14 in human body (one million times mass of tritium)
- Beta particle range in biological material about 300 µm[(2)] (greater than 30 times range of tritium beta)
- Biological half-life is 40 days, with primary excretion pathways being feces and exhalation
- C-14 body burden, significantly greater than tritium, presents no biological hazard to humans

Biological Tritium in Perspective (cont.)

- Potassium-40 emits beta particle with energy of 1330 keV (greater than 70 times energy of tritium beta) as well as 1461 keV gamma-ray
- K-40 most common radioisotope in human body
- Potassium ≈ 0.18% of body weight;[1] K-40 ≈ 0.0117% of potassium[2] → ≈ 0.015 gram K-40 in human body (one trillion times mass of tritium)
- Average biological half-life is ≈ 16 days,[3] excreted from human body primarily through urine
- K-40 contained in food we eat and presents no biological hazard to humans

Natural Radioactivity in Food

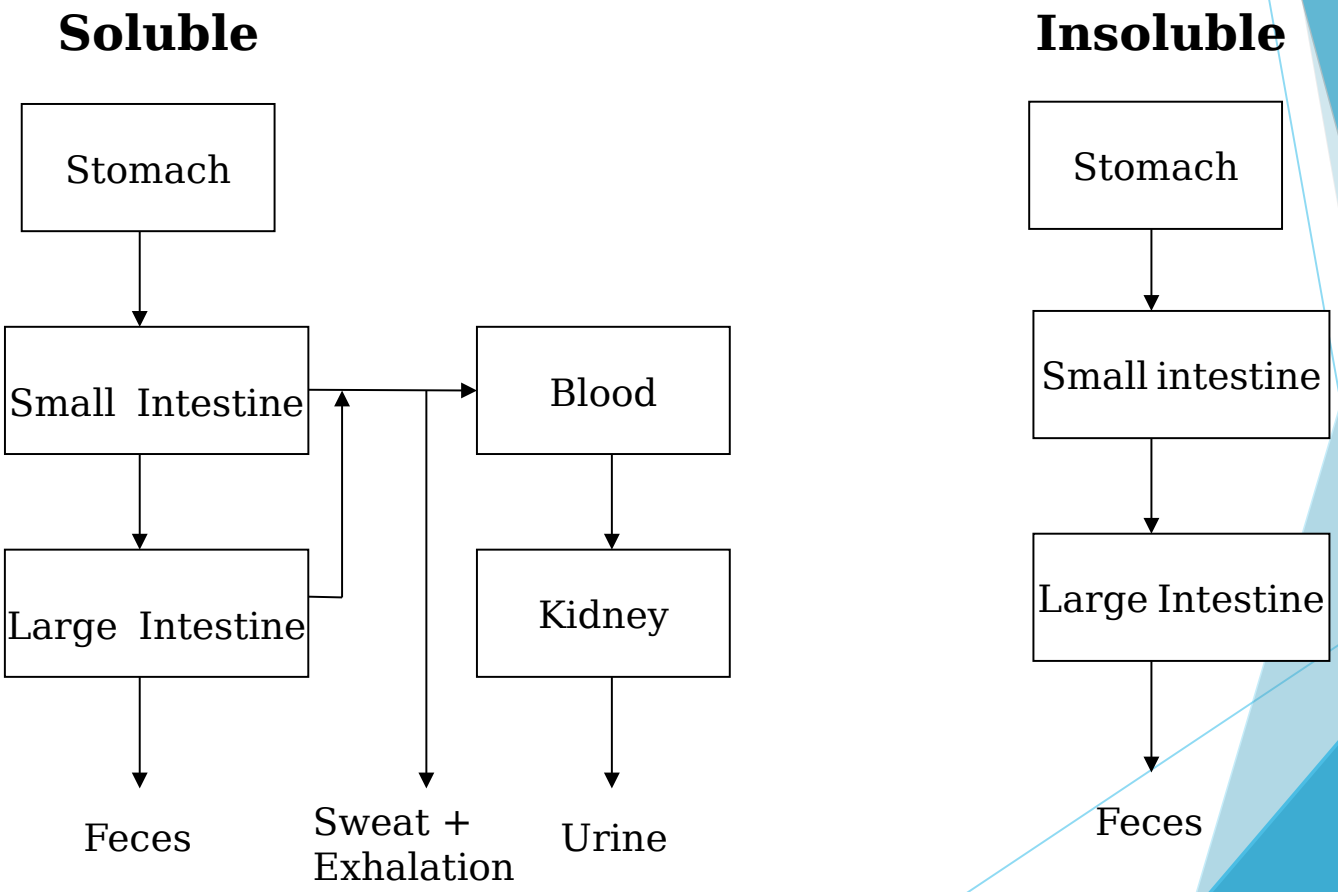
Food	^{40}K (β,γ) pCi/kg	^{226}Ra (α) pCi/kg
Brazil Nuts	5600	1000-7000
Lima Bean	4640	2-5
Banana	3520	1
White Potato	3400	1-2.5
Carrot	3400	0.6-2
Red Meat	3000	0.5
Low-sodium Salt	3000	---
Beer	390	---
Drinking Water	---	0-0.17

GI Absorption of Radionuclides

Isotope	Radiation	Half-life	GI Absorption
Hydrogen-3 (Tritium)	β	12.3 years	100%*
Carbon-14	β	5730 years	> 90%[1]
Potassium-40	β,γ	1.26×10^9 years	90%[2]
Strontium-89	β	50.5 days	30%
Strontium-90/Yttrium-90	β	28.8 years	30%
Iodine-131	β,γ	8 days	100%
Cesium-137	β,γ	30 years	100%

* Tritiated water can also be absorbed through the skin

Biological Radionuclide Excretion Pathways



Radioactive Elements in Human Body

Radioactive Isotope	Half Life (years)	Isotope Mass in the Body (grams)	Element Mass in the Body (grams)	Activity within the Body (Disintegrations/sec)
Potassium-40	1.26×10^{9}	0.0165	140	**4,340**
Carbon-14	5,730	1.6×10^{-8}	16,000	**3,080**
Rubidium-87	4.9×10^{10}	0.19	0.7	600
Lead-210	22.3	5.4×10^{-10}	0.12	15
Tritium (H-3)	12.43	2×10^{-14}	7,000	**7**
Uranium-238	4.46×10^{9}	1×10^{-4}	1×10^{-4}	3 - 5
Radium-228	5.76	4.6×10^{-14}	3.6×10^{-11}	5
Radium-226	1,620	3.6×10^{-11}	3.6×10^{-11}	3

Source:
http://www.rerowland.com/BodyActivity.htm

Tritium Releases to Environment

- Routine authorized releases of tritiated water from U.S. nuclear power plants closely monitored by nuclear utilities and reported to Nuclear Regulatory Commission (release information available on NRC website)
- Abnormal releases from nuclear power plants always evaluated by NRC
  - Offsite releases never found to be high enough to adversely affect public health and safety

Tritium Releases to Environment (cont.)

- Millions of gallons of slightly tritiated water released to oceans, large lakes, and large rivers from world's nuclear power plants every year
  - Has been occurring for decades in accordance with globally accepted nuclear safety standards
  - No observed adverse effects on environment or humans

Annual Discharge of Tritium from Nuclear Facilities							
Location	Nuclear Facility	Closest waters	Liquid (TBq)	Steam (TBq)	Total (TBq)	Total (mg)	Year
United Kingdom	Heysham nuclear power station B	Irish Sea	396	2.1	398	1,115	2019
United Kingdom	Sellafield reprocessing facility	Irish Sea	423	56	479	1,342	2019
Romania	Cernavodă Nuclear Power Plant Unit 1	Black Sea	140	152	292	872	2018
France	La Hague reprocessing plant	English Channel	11,400	60	11,460	32,100	2018
South Korea	Wolseong Nuclear Power Plant and others	Sea of Japan	211	154	365	1,022	2020
Taiwan	Maanshan Nuclear Power Plant	Luzon Strait	35	9.4	44	123	2015
China	Fuqing Nuclear Power Plant	Taiwan Strait	52	0.8	52	146	2020
China	Sanmen Nuclear Power Station	East China Sea	20	0.4	20	56	2020
Canada	Bruce Nuclear Generating Station A, B	Great Lakes	756	994	1,750	4,901	2018
Canada	Darlington Nuclear Generating Station	Great Lakes	220	210	430	1,204	2018
Canada	Pickering Nuclear Generating Station Units 1-4	Great Lakes	140	300	440	1,232	2015
United States	Diablo Canyon Power Plant Units 1,2	Pacific Ocean	82	2.7	84	235	2019

Tritium Releases to Environment (cont.)

- Fukushima Tritiated Water Task Force 2016 Report identified 760 TBq of tritium (≈ 2.1 grams or 14 mL of HTO) contained in 860,000 m^3 of onsite stored water
- Tritiated water to be diluted with seawater to 1500 Bq/L before ocean discharge via 1 km long undersea tunnel[1,2]
  - One-fortieth concentration allowed by Japanese drinking water
    safety standards
  - One-seventh World Health Organization guideline for drinking water
- Final tritium concentration about 2.3 x 10^{-6} Bq/L following 10-year discharge to North Pacific Ocean[3] – absolutely no health concern to aquatic life or humans

The Burning Question

- Whereas both C-14 and K-40 body burdens are much greater than the tritium body burden,
- Whereas both C-14 and K-40 emit higher energy beta particles than tritium (K-40 also emits high energy gamma-ray),
- Whereas C-14 and K-40 are not radiological health hazards,
- And since the Fukushima tritiated water concentration is below drinking water regulatory limits, why is discharging it to the ocean a problem?

The Sad Answer

As with other nuclear issues, tritium is a political problem, not a real problem.